

S E C R E T

REPORT TO  
COMMITTEE OF OPERATIONS ANALYSTS  
ECONOMIC EFFECTS OF SUCCESSFUL AREA ATTACKS  
ON  
SIX JAPANESE CITIES

4 September 1944

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NOTE: This report is preliminary in character and deals only with the economic effects of successful urban area attacks. A separate report with respect to estimates of force requirements is in process of preparation and should be available shortly.

S E C R E T

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## PREFACE: FINDINGS AND CONCLUSIONS

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Japanese manufacturing output. In major war industries (ammunitions, vessels and chemicals), the average loss would be 20 percent of one year's output.

This production loss results from two elements:

- (a) Direct damage to industrial and housing facilities;
- (b) The diversion of Japanese industry from its normal activities to the repair and replacement of this damage.

The direct production loss due to incendiary damage would be distributed among a number of industries, among them certain producers of front line equipment: aircraft components (loss of 20 percent of one year's output), tanks and trucks (13 percent), radio and radar (11 percent), aircraft engines (8 percent), ordnance (7 percent). The apparent existence of considerable stocks of aircraft components and of excess manufacturing capacity in tanks and trucks would probably prevent substantial reduction in final output in these categories. It is doubtful if losses of the magnitude indicated in other categories would have a perceptible effect front line strength.

The loss imposed by the burden of repair and replacement of incendiary damage would fall most heavily on the construction and machine tool industries. Since these industries lie deep in the productive process, the effect on front line strength would be delayed and diffuse. It has been assumed in this study that these basic industries would be capable of meeting the burden of repair and replacement resulting from the attacks within a six-month period. This assumption will be examined critically in a future study. If it should prove to be incorrect, the loss of production resulting from the attacks would be greater than stated in this report.



## PREFACE: FINDINGS AND CONCLUSIONS

1. FINDINGS.

This study attempts to assess the economic effects of incendiary attacks which destroy 70 percent of the housing in six major Japanese cities: Tokyo, Kawasaki, Yokohama, Osaka, Kobe and Nagoya. These attacks, it is estimated, would result in a loss equal to 15 percent of one year's total Japanese manufacturing output. In major war industries (munitions, metals and chemicals), the average loss would be 20 percent of one year's output.

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## II. CONCLUSIONS

Final judgment on the desirability of incendiary area attacks on Japan cannot be formed until a study of force requirements, now under way, is completed, and studies have been made of alternative target systems. However, one conclusion emerges clearly.

Area incendiary attacks should be undertaken only when it is possible to conduct them in force and to complete the planned destruction of all six cities within a period of a few weeks. A lack of concentration in the attacks will substantially diminish their effects.

In addition, two tentative conclusions appear warranted.

Incendiary attacks on congested urban areas will produce very great economic loss, measured in man months of industrial labor -- probably greater loss per ton of bombs despatched than attacks on any other target system. But because of the wide diffusion of this loss over many industries it is unlikely that output in any one important category will be so reduced as substantially to affect front line strength. (Precision attacks, assuming adequate intelligence and operational feasibility, can achieve such effects).

Area attacks might, however, significantly increase and prolong losses affected by precision attacks on war industries. The direct loss they impose on war production is not inconsiderable. Their effect in delaying recuperation of vital factories damaged in precision attacks is of greater importance. Area attacks, for example, will do substantial damage to the machine tool industry and at the same time impose upon this industry an enormous replacement burden. Under such conditions, the task of reorganizing a munitions industry heavily damaged in precision attacks becomes far more difficult.

The findings of this report are preliminary and will be revised to the extent required, which is being estimated in a separate report, as more complete data become available.

Comparable studies of precision attacks on specific target systems are necessary for a judgment as to the most efficient use of the available striking force.

An analysis of the probable effects of hypothetical attacks on various targets about which information is not complete necessarily involves the making of certain assumptions. In addition to the



SUMMARYI. INTRODUCTIONFindings of the Study

This study attempts to estimate the probable effect on Japanese war production of area incendiary attacks which are assumed to destroy 70 percent of the housing in six important industrial cities. It concludes that such attacks would impose on Japan a direct production loss equal to 7 percent of one year's production. For priority industry (munitions, metals, machinery, and chemicals) the figure rises to 10 percent. And for certain of these priority industries it would rise even higher. Aircraft components, for example, would suffer a 20 percent loss; tanks and trucks would experience a 13 percent loss; machinery, tools and instruments, 12 percent; radio and radar, 11 percent. Other categories of priority industry and all non-priority industry would suffer less. Tentative estimates of the burden of repair and replacement of damaged stocks, machinery and industrial buildings bring the total average loss to approximately 15 percent of one year's production; in priority production, the figure is 20 percent.

Purpose

The study was undertaken to provide data which would be used in relating the results to be expected from area incendiary attack to the effort required, which is being estimated in a separate report. Comparable studies of precision attacks on specific target systems are necessary for a judgment as to the most efficient use of the available striking force.

Assumptions

An analysis of the probable effects of hypothetical attacks against targets about which information is not complete necessarily requires the making of certain assumptions. In addition to the



basic assumption that it is operationally feasible to destroy 70 percent of the housing in the cities studied, the important further assumptions made in this paper are:

- a. That the damage is not sufficiently great to overwhelm Japanese repair facilities.
- b. That Japanese administrative controls do not suffer a major breakdown, and that the civilian population is not permanently demoralized.
- c. That the attacks are made in force, and that all cities are attacked within a period of a few weeks.
- d. A series of assumptions (described in Section IV) concerning the location and vulnerability of the large number of unidentified factories, both of priority and non-priority classification.

## II THE TARGET CITIES

### Population

The six cities included in this study -- Tokyo, Kawasaki, Yokohama, Osaka, Kobe, and Nagoya -- have a combined population (estimated as of July, 1944) of 14,908,000, approximately 20 percent of the total population of Japan Proper. They contain more than one-third of all workers in Japanese manufacturing plants and nearly one-half of all workers in priority industries. (The term priority industries as used in this study includes aircraft, shipbuilding, tanks and trucks, ordnance, radio and radar, machinery, tools and instruments, metals and chemicals -- the industries on which the Japanese war effort most directly depends.)

### Industrial Concentration -- Comparison with Germany

No other industrial nation is dependent on so small an area for so substantial a portion of its manufactured products as is Japan. These six cities provide a far more concentrated target than do cities containing a comparable amount of German industry. All 25



of the principal German target cities for the RAF offensive of 1943 do not contain as high a percentage of the country's industry as do these six of Japan. Comparative figures showing the relative importance of the industrial concentration in these two groups of cities in the total war economy of the two countries are presented in the following table:

TABLE I

Relative Importance of 6 Japanese and 25 German Cities

To War Production in Their Respective Countries

	<u>6 Japanese Cities</u>	<u>25 German Cities</u>
% of total population	20	25
% of total industry	35	24
% of priority industry	48	31
% of aircraft	71	30
% of aero-engines	66	48
% of metals	53	28
% of machine tools	64	55
% of shipbuilding	25	20
% of chemicals	27	30

Vulnerability

The construction in these cities is largely of wood (over 90 percent of all buildings in the more congested residential areas of wooden construction), and they are characterized by a very high degree of inflammability. In the central areas of most of the cities, roofs cover 50 to 80 percent of all ground, and the percentage runs as high as 40 to 65 for the whole of Zones I and II, the assumed area of attack.

Although data on the location of plants are far from complete, nearly 60 percent of identified priority targets in the six cities are in the conflagration zones, so that in addition to residential destruction, damage could be expected to a substantial portion of industrial installations.

Losses are unevenly distributed among industrial categories; the range is from 2 percent in the case of textiles to 41 percent in aircraft components. The general machinery, tools, and



### III. DAMAGE INFLECTED AND RESULTING PRODUCTION LOSS

#### Damage

The attacks assumed in this study would effect a degree of destruction never before equalled. Hamburg, with 56 percent of its housing destroyed or seriously damaged, suffered the heaviest losses among German cities attacked by the Allied Air Forces; the six Japanese cities, it is assumed, will suffer an average loss by complete destruction of 70 percent of their housing. From the production loss estimates were arrived at by combining loss caused by destruction and loss caused by direct damage to industrial facilities, an additional 7,750,000 will be dehousing; more than 500,000 fatal casualties will be suffered; nearly 40 percent of all identified priority plants will be seriously damaged; and non-priority plants located in more inflammable buildings and more concentrated in congested districts, will suffer an even greater degree of damage.

#### Total Production Loss

The total estimated loss from absenteeism and direct damage to industrial plants (without taking account of replacement costs) amounts to 7,600,000 man-months of labor in the six cities, or an average of ten weeks' loss for each of the 3,200,000 industrial workers located in the six cities. This loss is equivalent to a little over three weeks' production of the whole Japanese economy, or 7 percent of one year's production. Because of the concentration of priority industries within these cities, loss within these categories is greater. Total losses in priority industries amount to 5,900,000 man-months--about five weeks' production in priority industries in Japan as a whole, or 10 percent of one year's production.

#### Production Loss by Industries

Losses are unevenly distributed among industrial categories; the range is from 2 percent in the case of textiles to 20 percent in aircraft components. The general machinery, tools, and in-



struments group suffers a 12 percent loss. Tanks and trucks also suffer heavy loss (13 percent). Moderate losses are inflicted on radio and radar (11 percent), the general metals category (9 percent), and aircraft engines (8 percent). Losses are relatively minor in the case of ordnance (6.5 percent), chemicals (6 percent), aircraft assembly (4 percent), and shipbuilding (2 percent). (See Chart II).

#### IV. ABSENTEEISM AND DIRECT DAMAGE

Production loss estimates were arrived at by combining loss caused by absenteeism and loss caused by direct damage to industrial installations. (See Chart I). Absenteeism causes industrial loss when workers fail to report for work in plants which are capable of operating. Industrial damage causes production loss until repairs have been effected. Loss from these two factors is obviously not altogether additive. If a plant is almost completely destroyed, absenteeism will not be a factor of any significance.

#### Absenteeism

In computing the probable amount of absenteeism which would result from the 70 percent destruction of housing postulated, British experience has been used as a guide, but the method employed has been modified to take account of elements peculiar to Japan.

Upon analysis, the principal factors contributing to absenteeism following an incendiary attack prove to be firefighting, casualties, dehousing (including the relocation of workers, the clearance of debris, and the diversion of labor to new construction), the impairment of transportation, and social disorganization.

The total loss from absenteeism is estimated to be equal to one month's production of all industrial workers in the cities attacked. The relative importance of the various factors in producing these losses is indicated in the following table:

Firefighting	43,000	37,000
Casualties	60,000	30,000
Dehousing	100,000	80,000
Transportation	25,000	12,000
Social disorganization	250,000	240,000



TABLE II

CONTRIBUTION OF VARIOUS FACTORS TO TOTAL ABSENTEEISM

	Percent of Total Loss
Firefighting, etc.	12
Casualties	14
Dehousing (Relocation, debris clearance, new con- struction)	40
Transport dislocation	17
Social disorganization	17
TOTAL	100

Absenteeism from Firefighting

Firefighting against conflagrations of the dimensions assumed will require the efforts of a large part of the civilian population. On the basis of available information about ARP organization in Japan and the characterization of past conflagrations, it is assumed that firefighting activities will occupy the time of about half the labor force over a four-day period. First aid activities, time spent caring for injured family members, etc., will add to this figure.

Absenteeism from Casualties

The ratio of fatal casualties estimated to total population corresponds closely to that experienced in the Tokyo fire which accompanied the earthquake of 1923. Taking into account the significant characterizations of the various cities, an experienced fire staff estimated the probable casualties (persons killed, missing or seriously injured) to be expected as a result of the attacks. These estimates appear in the following tables:

TABLE III

CASUALTIES CAUSED BY ATTACKS

Cities	Casualties	Worker Casualties*
Tokyo	260,000**	135,000
Yokohama	45,000	22,000
Kawasaki	20,000	10,000
Nagoya	60,000	30,000
Osaka	150,000	80,000
Kobe	25,000	13,000
TOTAL	560,000	290,000

\* Worker casualties were estimated by applying the percentage of



workers in each city to the total number of casualties.

\*\* Tokyo casualties are based on the assumption that four attacks will be required to effect the 70 percent level of destruction. All other estimates are based on the assumption that the indicated destruction will be accomplished by one attack.

Some 290,000 casualties among industrial workers would, it is estimated, cause a loss within four months equal to about  $4\frac{1}{2}$  days production of the entire labor force.

#### Absenteeism from Dehousing

Even assuming 25 percent evacuation of the total population of the six cities, the destruction of 70 percent of all houses would leave 7,750,000 dehousing people. Under a system of compulsory billeting, with the allocation of 40 square feet per person, the housing available after the attacks would be able to accommodate approximately 8,600,000 of the total population of 10,310,000 which would remain in the devastated cities. Relocating these millions would require time and cause considerable absenteeism. New construction would be required for about 1,170,000. Before new construction could be commenced and utilities required, a considerable amount of debris clearance would have to be undertaken, the individuals burned out would no doubt spend some time attempting to salvage possessions from the ruins. It is assumed that about half the persons requiring new housing would be provided for in hutments largely of their own construction, the building of which would contribute to industrial absenteeism. These three factors, it is estimated, would produce a total loss equal to more than 12 working days of the entire labor forces. Relocation alone would be equal to nearly 9 working days of the entire labor force.

#### Absenteeism from Social Disorganization

The estimate of loss from social disorganization presented in this paper is based on the assumption that the Japanese will be no less efficient than the Germans in their maintenance of order and administration of medical aid, emergency relief, evacuation and emer-



agency housing. The German ARP organization, built up gradually as the weight of the RAF attacks increased, was seldom overwhelmed. When it was, as in the case of Hamburg, chaotic conditions ensued. The destruction assumed in these Japanese cities would be on a scale beyond anything the Germans were called on to meet. If a series of saturation attacks against all six targets should be launched without any preliminary period of small-scale area attacks during which the Japanese could develop and improve their organization and techniques, it is possible the defenses might be overwhelmed. The economic effects of such a debacle - without regard to its effects on morale, and its possible immediate military significance - might be of a magnitude beyond anything in European experience. On the basis of European experience, however, which provides the only objective standard available, it is estimated that this factor would cause a loss equal to 5 working days of the entire labor force, over and above losses from all other causes.

#### Absenteeism: Additional Loss by Reason of Unbalanced Labor Force.

In addition to the average loss of time by all workers, estimated to equal one month, there would be a further loss in output - estimated as an additional week - due to the reduced efficiency of those reporting for work. This would be caused partly by the condition of workers reporting, and partly by the unbalanced character of the force available in many plants. The total average loss from absenteeism and reduced efficiency is therefore estimated at five weeks.

#### Absenteeism: Impact on Priority and Non-Priority Industries

Since the authorities, by providing special facilities for certain categories of workers, and by directing labor from one industry to another, can within limits determine which sectors of the economy will bear the major burden of absenteeism, priority industries are certain to suffer less than the average loss. It seems reasonable to assume that the average loss for workers in priority industries would be of the order of four weeks, and in non-priority industries six weeks.



Direct Damage

A pre-attack assessment of loss from direct damage to industrial installations poses two problems: first, the determination of what damage will be done; second, the translation of that damage into economic loss.

To determine probable damage, it is necessary to locate plants and to estimate their physical vulnerability. Paucity of data has made the task difficult. Information is available, however, concerning the location of many of the important pre-war installations. Some 317 identified priority plants account for an estimated 55 percent of all priority production in the six cities. For purposes of this study, Japanese industrial plants were divided into three groups: (1) identified priority plants; (2) unidentified priority plants; (3) non-priority plants (unidentified).

Direct Damage to Identified Plants

A staff of expert fire engineers estimated the likelihood of damage to all the identified priority plants, taking into consideration their location, their physical vulnerability, and the assumed spread of the conflagration. In making these estimates, the likelihood of direct hits was calculated on the basis of an assumed density of attack averaging 20 tons per square mile.

Direct Damage to Unidentified Plants -- Priority and Non-Priority

The extent of employment in unidentified priority plants of each category in each city was determined by subtracting the number of workers assigned to the identified plants from the total in the category estimated to be employed in the city. In some cases, identified plants accounted for all priority workers. Where they did not, one of two principles was followed in allocating unidentified plants to zones. If the location of identified plants seemed to form a pattern, as in the shipbuilding industry in Osaka, unidentified priority plants were allocated to zones in the same proportion. Where location seemed to be at random, as in machinery, tools and instruments in Tokyo, unidentified priority plants were apportioned to the various zones in proportion to the number of residences in these



zones. It was assumed that nearly all non-priority plants would be old, and located predominantly within the central areas. They were apportioned to Zones I and II on the basis of the percentage of residences in those zones. All unidentified factories apportioned to Zones I and II were assumed to suffer 60 percent destruction from fire. The validity of these assumptions is discussed in the conclusion.

#### Direct Damage: Translation into Economic Loss

On the basic assumption, derived from British experience and other evidence, that production loss for each damaged factory was equivalent to six months' production of the burned-out area, physical damage was converted into economic loss. Where excess capacity exists, as in the non-priority industries, it was assumed that damage to installations would affect production for only three months.

#### Calculation of Total Loss

In adding loss caused by absenteeism to loss caused by direct damage, a rule of thumb was used which provided for the addition of production loss from absenteeism to production loss from damage to installations when the latter was of the order of 33 1/3 percent or less; when physical damage was in excess of 33 1/3 percent, no additional loss was assumed to occur because of absenteeism.

#### V. COST OF REPAIR AND REPLACEMENT

Production loss in Germany was only a minor portion of the total loss imposed by area bombing. The cost of repair and replacement of damaged goods and buildings proved to be the major cost imposed on economy. (In 1943, of the total loss of approximately 7.4 percent of one year's German industrial production, 2.2 was attributed to production loss and 5.2 to repair and replacement.) The burden of repair and replacement of damaged machinery, stocks, and buildings is important because it diverts labor from other work, and because it is concentrated principally on a few industries, such as iron and steel, electrical engineering, and machine tools, which may be unequal to the effort.



Method of Calculating Repair and Replacement Costs

It has not been possible at this stage to undertake detailed estimates of the costs of repair and replacements to Japan, but an attempt has been made to assess their general magnitude, and certain tentative conclusions have been reached. In making these tentative estimates, factors used in assessing damage to industrial buildings, equipment and stocks in Germany have been applied to the estimates of damage to Japanese factories. These factors were worked out mainly from British data, and insofar as Japanese conditions and practices vary from the British, they introduce a margin of error. It is necessary to point out that this margin of error may be great.

Total Cost.

The application of these factors to the estimates of damage to Japanese factories already developed yields the following results:

	Thousands of <u>man-months</u>
Cost of repairing or reconstructing factory buildings	3,200
Cost of replacing destroyed machinery and other equipment	3,600
Cost of replacing destroyed stocks of finished goods and work in process	<u>2,000</u>
TOTAL	8,800

Practically all the burden of replacing equipment and stocks will fall on priority industries. Most of the burden of repairing building damage would fall on the construction industry and on the producers of building materials, which, except for metals and chemicals,\* are primarily non-priority. The total loss comprises 5,900,000

\* The category chemicals as employed in Japanese official statistics includes glass and cement. Obviously, the repair burden on these portions of the chemical industry would have little direct military significance.



man-months in priority industries; 1,900,000 man-months in non-priority industries.

These estimates do not include allowance for destruction of factories in non-priority industries, of non-industrial buildings and installations, nor of stocks of goods in warehouses.

When added to the estimates of direct production loss, these figures bring the total loss inflicted by the attacks to approximately 16,500,000 man-months, equivalent to almost two months total Japanese output. Approximately 12,000,000 man-months are in priority industries, equivalent to more than two months of total annual output in this category. (See Chart I)

#### Incidence of the Burden

The repair and replacement burden is heavily concentrated on the construction and equipment industries. Although the analysis is too tentative to permit any firm conclusions, the possibility seems to exist that the impact of demands on certain of these industries--notably the machine tool industry--may so far exceed their capacity that the effect of the attacks would be prolonged well beyond the six-months period assumed on the basis of British and German experience. The ability of the replacement industries to bear this burden is being made the subject of a special study. Pending the completion of this study, it is tentatively estimated that the construction and equipment industries will have to devote their whole resources to replacing damage for about two months, and that in some sectors of these industries--e.g., machine tools--the burden will be the equivalent of at least eight months' production at pre-attack rates of output. When it is considered that a substantial portion of machine tool capacity will be destroyed in the attacks, and that a large part of the output of the remaining plants will be required to make good the damage in the industry itself, the possibility of producing serious and long-lasting dislocation of a considerable portion of the entire Japanese productive machine appears promising.



## VI. CONCLUSION

### Results of the Attacks -- Comparison with Germany.

The great concentration of industry in the six Japanese cities studied in this report, together with their high degree of inflammability, makes them peculiarly suited to area incendiary attacks. Attacks of the degree of effectiveness assumed in this report would produce economic losses of far greater magnitude than those experienced in the European Theater. A comparison of the results estimated to follow successful attacks on the six Japanese cities with the results of the area bombing of Germany is illuminating.

The RAF in 74 full-scale attacks on 25 German cities in 1943 dropped nearly 100,000 tons of bombs to achieve an average level of 25 percent destruction or serious damage to houses in these cities, and to render 4,500,000 persons homeless. On the basis of the assumptions employed in this report, a fraction of this effort directed at six Japanese cities would destroy 70 percent of their housing, rendering 7,750,000 people homeless. Germany suffered an estimated direct production loss of 2.2 percent of one year's industrial output, a total loss of about 7.5 percent. The corresponding figures for Japan are 7 percent and 15 percent; for priority industry total loss rises to 20 percent. The highest direct production loss imposed on Germany was 7 percent of one year's machine tool output. The Japanese loss in the general category of machinery, tools and instruments is 12 percent, in aircraft components it is 20 percent.

### Validity of Statistical Results.

The statistical findings of this report are liable to two principal errors. Estimates of damage to factories are possibly high; the procedure used in assessing factory vulnerability may have assigned too large a portion of unidentified plants to the conflagration zone, and may have taken insufficient account of the possible construction of fire breaks. If unidentified plants, contrary to the



assumptions employed in this report, were to prove no more vulnerable than identified plants, loss from damage to plants would be reduced by 1,440,000 man months -- a loss only in small part compensated for by an increase of 200,000 man months loss from absenteeism. Production loss would be diminished from 7 to 5 percent of one year's output; and total loss (production loss plus repair and replacement costs) would fall from 15 percent to 11 percent.

Estimates of the duration of loss, on the other hand, are quite possibly too low. The preliminary analysis undertaken in this report suggests that the replacement demands on certain industries -- notably the machine tool industry -- may greatly exceed their capacities, extending the period required for recuperation far beyond the six months allowed in this study.

The estimates of this report assume that attacks would be sufficiently concentrated to prevent the dissipation of their effects, but not so concentrated as to overwhelm defenses and government administration. If the attacks should be only sporadic and extend over a considerable period of time, loss from absenteeism and factory damage would be reduced and the problem of repair simplified. The estimates made in this study will accordingly be too high. There is reason to believe that a sudden series of saturation attacks against all six targets may overwhelm the untried Japanese ARP organization and the administration, creating chaotic conditions. If this situation should be produced, economic losses would be more serious than those estimated.

#### Recommendations

No recommendation concerning the desirability of including incendiary attacks on Japanese cities in a general bombing program is possible until a more satisfactory estimate has been made of force

The findings of this report are preliminary, and will be revised as more complete data become available. The findings of this study are preliminary, and will be revised as more complete data become available.

One definite conclusion emerges from the present study: area attacks should not be commenced until it is possible to conduct them



in force and to complete the entire program within a period of a few weeks.

Some additional conclusions of a tentative nature appear to be warranted by the magnitude and character of the production loss resulting from these attacks.

The amount of loss -- measured in total man months -- is extremely large, probably considerably larger per ton of bombs than could be achieved by attacks on any other type of target. It is, on the other hand, highly diffused, affecting all industries to some extent, and crippling no industry engaged in the production of finished munitions. Much of the loss will not be felt for many months.

It is possible that attacks on precision systems may achieve effective concentration on industries of strategic importance and affect military strength within a brief period.

Area attacks would seriously damage the machine tool and other equipment industries, and would impose a heavy replacement demand on their capacity; if area attacks are made subsequent to attacks on specific target systems, these effects would delay the recuperation of factories damaged in the precision attacks. A more accurate assessment of this possibility will be possible upon the completion of the study of the capacity of the replacement industries now in progress.

The social and administrative disorganization which would be produced by these attacks might prove valuable as an adjunct to invasions.

These conclusions all apply to incendiary attacks on congested urban areas. The desirability of attacking specifically industrial urban areas with heavy combined HE-IB loads has not yet been considered.

The findings of this report are preliminary, and will be revised as more complete data become available. The problem of recuperability will be dealt with in a supplementary report. An estimate of force requirements is also in process of preparation.